Renewable and Sustainable Energy Reviews 32 (2014) 526–531

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Train travel passengers' willingness to pay to offset their CO_2 emissions in Korea ☆

Hea-Jin Lim [a,1], Seung-Hoon Yoo [b,*]

[a] Technology Policy Research Institute, Korea Institute of Science and Technology, 5 14-Gil, Hwarang-Ro, Sungbuk-Gu, Seoul 136-791, Korea
[b] Department of Energy Policy, Graduate School of Energy & Environment, Seoul National University of Science & Technology, 232 Gongreung-Ro, Nowon-Gu, Seoul 139-743, Korea

ARTICLE INFO

Article history:
Received 28 June 2011
Received in revised form
22 November 2013
Accepted 4 January 2014
Available online 5 February 2014

Keywords:
Voluntary carbon offsets
Contingent valuation
Willingness to pay
One-and-one-half bound dichotomous choice

ABSTRACT

Due to the upsurge in concerns regarding climate change, the carbon market has been growing more rapidly than ever. Recently, a more innovative and experimental voluntary carbon market has been playing a supplementary role to the compliance market, which is lacking in flexibility and diversity, and has been accounting for an increasingly larger portion of the carbon market. Among the efforts to accumulate data and develop appropriate policies for the voluntary carbon market, it is necessary to analyze the benefits of carbon offsets for GHG emissions from railways. This study attempts to apply contingent valuation (CV) to measure the public's willingness to pay (WTP) for voluntary carbon offsets (VCOs) from railway travel in Korea. Furthermore, in order to enhance the statistical efficiency of the WTP estimation and reduce the response effect in the context of WTP elicitation, this study employs a one-and-one-half bound dichotomous choice format. The estimate of the mean WTP for a VCO program for a specific travel distance is estimated to be KRW 1,345 (USD 1.24) per person. This quantitative information can be utilized to develop policies related to mitigating climate change.

Contents

1. Introduction

According to the fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC), the average temperature on earth has risen by 0.7 °C over the past 100 years, and it is again confirmed that climate change is not a natural phenomenon but an artificial catastrophe due to greenhouse gas (GHG) emissions [1]. Detailed rules for the implementation of the Kyoto Protocol

☆Paper prepared for consideration for publication in Renewable and Sustainable Energy Reviews.

* Corresponding author. Tel.: +82 2 970 6802; fax: +82 2 970 6800.
E-mail addresses: hjlim@kist.re.kr (H.-J. Lim), shyoo@seoultech.ac.kr (S.-H. Yoo).
[1] Tel.: +82 2 958 6019, fax: +82 2 958 6922.

1364-0321/$ - see front matter
http://dx.doi.org/10.1016/j.rser.2014.01.010

with the introduction of emissions trading as the main agenda were adopted at the third-parties meeting of the UN Framework Climate Change Convention (UNFCCC) in December 1997. Due to the increasing concern regarding climate change, since then, the carbon market has grown more rapidly than ever.

Carbon markets are divided into compliance markets that reduce GHGs under the Kyoto Protocol and voluntary markets that function outside of compliance markets. Not long after being introduced, a large number of interested parties entered compliance markets with a massive injection of capital, and these markets have become one of the most attention-grabbing trading markets at present. Therefore, much data and research have already been accumulated on these markets. On the other hand, voluntary markets, although having a longer history than compliance markets, feature participation by relatively few businesses and organizations; they are characterized by a relative lack of research material and experience.

However, recently more innovative and experimental voluntary carbon markets have been playing a supplementary role to compliance markets, which are lacking in flexibility and diversity; these voluntary markets account for a progressively greater portion of carbon markets. In particular, Korea was classified as a developing nation for the first commitment period (2008–2012) of the Kyoto Protocol, and so currently does not have obligations to reduce its greenhouse gas emissions compared with, say, the US.[2] Therefore, because it seems difficult for Korea to introduce a compliance market in a short period of time, the introduction and vitalization of voluntary markets can be the best action to cope with climate change at the national level [2–4]. Moreover, because it is certain that Korea, as the world's ninth-largest emitter of GHGs, will be committed to the Annex-countries after 2013 for the post-Kyoto system, it must introduce and operate a voluntary market as in the US, and accumulate experiences and data.

This study therefore uses stated preference techniques to investigate the willingness to pay (WTP) of private consumers for voluntary carbon offsets (VCOs) in the context of railway travel. To the best of our knowledge, it is the first study to do so.[3] Such measurements of passenger WTP help policy makers to outline effective instruments aimed at discouraging climate-unfriendly travel activities as well as to generate funds for measures that are directed towards climate change mitigation and adaptation [7–17]. Moreover, by focusing on train travel passengers, we also aim to contribute to the current policy developments regarding the control of GHG emissions from railways. Driven by the polluter-pays-principle, governments can implement various policy instruments for climate change mitigation regarding the railway industry and its passengers.

In particular, this paper employs a one-and-a-half bound (OOHB) dichotomous choice (DC) CV model for realizing statistical efficiency. Furthermore, in CV, respondents who say ‘no’ to the given bids can be divided into two groups: those who really have a zero WTP and those who have a positive WTP that is less than the second, lower bid. To address this problem, this paper applies a spike model. The remainder of the paper is organized as follows. Section 2 explains the relationship between railways and CO_2 emissions. Section 3 presents the methodology that is employed in this study. Section 4 reviews the issues with regard to survey design. A discussion of the results appears in Section 5, and some concluding remarks are made in the final section.

[2] Although the US refused to ratify the protocol and does not have the obligation to reduce GHG emissions, it has contributed much to the spread of voluntary carbon markets in such a way that not only have state governments, businesses and individuals voluntarily induced regulation systems and developed reduction projects, but also they have established the world's largest voluntary emission exchange, the Chicago Climate Exchange (CCX).

[3] MacKerron et al. [5] and Brouwer et al. [6] evaluated air travel passengers' WTP for VCOs.

2. The railroad industry and greenhouse gas emissions

As mentioned above, due to the adoption of the Bali Roadmap in December 2007, it is certain that Korea will be allocated to the Annex-countries from 2013. Accordingly, Korea has devised various action plans to reduce its carbon emissions efficiently. The Korean Government has created a UNFCCC task force and deployed all-round climate change response actions. In particular, Government has drafted a basic act on low-carbon green growth and established a 5-year green growth national plan, choosing three areas and 10 tasks and pushing forward the subsequent actions.

Transportation accounts for about 20–30% of the total CO_2 emissions. Rail is responsible for very little in the way of emissions (1–2%) [18]. Roads account for 81% of oil consumption and 71% of GHG emissions in transportation. To resolve these problems, the Korean Government has revealed a modal shift policy to switch from a road-centered to a rail-centered transport system. Therefore, the importance of railways as low-carbon vehicles is increasing and the GHG emission reduction efforts in transportation are very active. New modes, such as electric cars and fuel cell buses, have appeared, the Sustainable Eco-green Railway Program (S-ERP) 2020 has been developed and delivered since 2008 and the curtailment plan of energy consumption has been established by railway operation institutions [19].

Regarding GHG emissions in the railroad industry, the total emissions are expected to increase continuously and the emission intensity can be expected to reduce significantly. Therefore, emission intensity reduction through an increase in the share of transportation of railways is important, but strategic approaches to decreasing the total GHG emissions are essential. The International Union of Railways (UIC) in Europe has carried forward the Clean Development Mechanism (CDM) project. The Clean Development Mechanism (CDM), defined in Article 12 of the Protocol, allows a country with an emission-reduction or emission-limitation commitment under the Kyoto Protocol (Annex B Party) to implement an emission-reduction project in developing countries. Such projects can earn saleable certified emission reduction (CER) credits, each equivalent to 1 tonne of CO_2, which can be counted towards the Kyoto targets. In addition, the primary railway operating institutions in Europe have annually set targets for CO_2 emission reduction and worked out various strategies from 2000, mostly they have achieved the desired CO_2 reduction effect by substituting diesel as an energy source for trains [20].

The technological options to reduce GHG emissions in the domestic railway sector can be approached in terms of both energy consumption efficiency improvement and energy source conversion. To achieve energy efficiency improvement, it is necessary to develop energy-saving locomotive operations, such as Deutsche Bahn (DB) in Germany, and to improve heating/cooling and lighting facilities. In addition, the energy consumption savings effect can be expected through reducing the weight of vehicles. On the other hand, from the perspective of energy source conversion, securing a generic technology that can utilize renewable energy is preferentially necessary. Developments such as solar-powered station building, railroad vehicles that run on biodiesel, etc. can be included. Converting the waste energy created from railways into new energy is also possible. Through these options, GHG emissions in domestic railways can be efficiently reduced in terms of both emission intensity and total emissions [18].

This paper considers an alternative policy option for controlling the climate change impact of railways, which conforms to the polluter-pays principle, with the revenue being spent on carbon-offset activities including renewable energy or green electricity. Carbon or GHG offsets are certified emission reductions or sequestrations that can be purchased by an individual, business, or government to offset the emissions resulting from their activities. Although uncertainties

regarding the measurement and performance of GHG emission reductions have resulted in concerns about the credibility of offsets, there are now many commercial and non-profit providers of carbon offsets [5]. The purchase of offsets demonstrates to policy makers the public's support and willingness to pay for measures to tackle these concerns [21,22].

3. Methodology

3.1. Measurement method: contingent valuation method

The cornerstone concept that is used for measuring the social and environmental benefits from a proposed voluntary carbon offsetting program is the consumer's WTP for the program [23]. This concept represents the amount people would be willing to pay to avoid specified environmental damage, to achieve a stated improvement in environmental quality, or to receive a specified supply of a public good. The major objective of this study is to measure the economic benefits of controlling the climate change impact of railways for Korean households, thereby aiming to provide policymakers with at least a preliminary evaluation of any proposed carbon mitigation policy. To achieve this objective, we adopted a survey approach, namely, CV. This method involves constructing a hypothetical market or referendum scenario and uses questionnaires in a survey to elicit respondents' preferences for the new carbon offset program by finding out how much they would be willing to pay [24]. Respondents utilize the established hypothetical market to state their WTP or vote either for or against the new offsetting program at a particular tax (price). Furthermore, the CV method is acknowledged by the prestigious National Oceanic and Atmospheric Administration (NOAA) panel as a means of obtaining estimates that are reliable enough to be used as a starting point for administrative and judicial determinations.

3.2. Sampling and survey method

The sample for this research was restricted to the residents of Seoul, Incheon, and Gyeonggi. The total number of households in the area was 4,046,086. In order to draw a random sample from this population, sampling was conducted by a professional polling firm. The survey was implemented with heads of household or housewives whose age ranged from 20 to 55 in May 2009, and yielded 500 usable interviews. Thus, the findings from the survey are based on an analysis of 500 interviews. The survey could have been conducted by face-to-face interviews, telephone interviews, or mail. Among these methods, we chose face-to-face interviews with well-trained interviewers for the CV survey because they could offer the most scope for detailed questions and answers in Korea [25].

3.3. Elicitation method

When measuring respondents' WTP, most designers of CV studies have employed a referendum or DC question to elicit respondents' WTP in accordance with the NOAA's 'Blue Ribbon Panel' guidelines [26]. This DC question asks each respondent to accept or reject a suggested bid for offsetting their carbon emissions during a railway trip. Generally, the DC question format comprises a single-bound (SB) DC question and a double-bound (DB) DC question. The SB DC question asks the respondent only one closed-ended question. This model has some merits, such as apparent incentive-compatibility and the high degree of elimination of protestant bids. In the DB DC question, each respondent is presented with a sequence of two bids and is first asked for a 'yes' or 'no' vote as to whether or not his/her WTP is at least as high as the first bid. The second bid is conditional on the respondent's response to the first bid: it is lower if the first response is 'no' and higher if it is 'yes'. The gain in statistical efficiency arises from the series of WTP questions, allowing the researcher to bracket many of the respondent's WTP amounts between two monetary bids.

However, the DB DC has given rise to controversy because of evidence that the responses to the first bid may sometimes be inconsistent with the responses to the second with the latter revealing a lower WTP. A respondent, who says 'yes' to the initial price sees the second price as a price increase, which s/he rejects. Likewise, a respondent who says 'no' and is then offered a lower price may suspect that an inferior version of the item will be provided, which s/he is also inclined to reject. Cooper et al. [27] presented a solution to this problem by devising the so-called OOHB DC, a specification that should significantly reduce the risk of such a survey by moving into a bargaining setting in which the interviewer proposes a follow-up bid. In this new question format, the interviewee is given two prices upfront and informed that the exact cost is uncertain but known to be bounded by the two extreme prices.

The application of this methodology requires the interviewer first to inform the respondent about the limits on the expected cost of the VCO before asking the questions that elicit the respondent's WTP. These are referred to as the lower and upper bids. Next, the interviewer randomly chooses one of these two points as the initial value at which to elicit the respondent's WTP. Then, if the upper bid is chosen and the respondent says 'no', the respondent is asked if s/he is willing to pay the lower bid. Similarly, if the lower bid is the first value to be examined and the respondent says 'yes', s/he will be asked if s/he is willing to pay the upper bid. In the other two cases, the process of elicitation stops, i.e., when either the first price to be proposed is the upper bid and the respondent says 'yes' or the first price to be proposed is the lower bid and the answer is 'no' [28].

Furthermore, the results of a pre-test in a focus group were used to refine the range of bid amounts for the DC WTP questions. The respondents were randomly assigned to eight subgroups, with each sub-sample being asked to respond to a different set of bids (in Korean won).[4] The sets of bids used in this study were: (500, 1,500), (1,000, 2,000), (1,500, 2,500), (2,000, 3,000), (2,500, 3,500), (3,000, 4,000), (,500, 4,500), and (4,000, 5,000), where the first element of each set corresponds to the lower bid and the second element corresponds to the upper bid, which is higher than the lower bid by KRW 1,000.

3.4. Payment vehicle

The payment vehicle used for this study can include general taxes, such as a carbon travel tax [6], and a tax on various products that are frequently purchased, which are likely to be familiar to most respondents. Despite its high level of familiarity and obvious connection with the good being considered, it may encourage respondents to restrict their WTP amounts to the range associated with a fair or customary expenditure [24]. Therefore, the green premium, that is, a donation over and above the railway fare for the journey, was introduced. The WTP question format asked the respondents to imagine traveling from Seoul to Busan (408.5 km) by Korea Train Express (KTX) charged with 100% green electricity. They were then asked if they would be willing to pay a given bid amount in addition to the price of their train ticket. In this case, individuals just had to decide whether or not the value to them of the VCO program was at least worth this price. The WTP question was:

"Would your household be willing to pay a given extra amount on top of your train ticket to compensate for your contribution to

[4] Green electricity is defined as power that is produced from renewable resources (available at: http://www.recoveredenergy.com).

the greenhouse gas emissions of your specific railway travel distance, provided that the success of this program is guaranteed? If the majority of people are not willing to pay the green premium, renewable resource security and GHG emissions reduction would be threatened".

Regarding the definition of the green premiums that the households themselves were likely to bear, we used a provision point mechanism. The respondents were told that:

"The amount you indicate will tell us what it is really worth to your household to have the program implemented. If the policy actually costs less than people are willing to pay, you would only have to pay what it would cost. If the program turns out to cost more than people are willing to pay, it would not be implemented."

The information given to the respondents about all the aspects of the hypothetical market, together with such information as is provided on the good being valued, constitutes the framing of the good.

4. A model of WTP

4.1. The OOHB DC model

According to Cooper et al. [27], the OOHB DC-CV model can be described as follows. Let $i=1,\ldots,N$ be the index for respondents in the sample, and A be the bid amount presented to a respondent. Each respondent is presented with two prices, A_i^L and A_i^U, where $A_i^L < A_i^U$. If A_i^L is randomly drawn as the first price, then the possible responses are yes–yes, yes–no, and no. If A_i^U is randomly drawn as the first bid, then the possible answers are yes, no–yes, and no–no. The binary-valued indicator variables of these six possible outcomes are I_i^{YY}, I_i^{YN}, I_i^{N}, I_i^{Y}, I_i^{NY}, and I_i^{NN}, such that

$$\begin{aligned}
I_i^{YY} &= \mathbf{1}(i\text{th respondent's response is 'yes}-\text{yes'})\\
I_i^{YN} &= \mathbf{1}(i\text{th respondent's response is 'yes}-\text{no'})\\
I_i^{N} &= \mathbf{1}(i\text{th respondent's response is 'no'})\\
I_i^{Y} &= \mathbf{1}(i\text{th respondent's response is 'yes'})\\
I_i^{NY} &= \mathbf{1}(i\text{th respondent's response is 'no}-\text{yes'})\\
I_i^{NN} &= \mathbf{1}(i\text{th respondent's response is 'no}-\text{no'}),
\end{aligned} \tag{1}$$

where $\mathbf{1}(\cdot)$ is an indicator function, the value of which is one if the argument is true and zero otherwise.

WTP (hereafter denoted as C) is recognized as a random variable with a cumulative distribution function (cdf) defined here as $G_C(\cdot;\theta)$, where θ is a vector of parameters. Given the assumption of a utility-maximizing respondent, the log-likelihood function takes the following form:

$$\begin{aligned}
\ln L = \sum_{i=1}^{N} \{ & (I_i^{YY}+I_i^{Y})\ln[1-G_C(A_i^U;\theta)]\\
& +(I_i^{YN}+I_i^{NY})\ln[G_C(A_i^U;\theta)-G_C(A_i^L;\theta)]\\
& +(I_i^{N}+I_i^{NN})\ln G_C(A_i^L;\theta)\}.
\end{aligned} \tag{2}$$

Following the practice of previous studies, formulating $1-G_C(\cdot)$ as a logistic cdf and combining this with $\theta=(a,b)$ yields $G_C(A;\theta)=[1+\exp(a-bA)]^{-1}$. Let C^+ be the mean WTP, when C can be positive or negative. Thus, the mean WTP (C^+) can be computed as $C^+=a/b$ [28].

4.2. The spike model

The respondents, who report 'no' and 'no–no', are composed of two groups: those who really have a zero WTP and those who have a positive WTP that is less than the lower bid. For those respondents who gave a 'no' response in the case that the lower bid was the starting price and a 'no–no' response-sequence in the case that the upper bid was the starting price, a third follow-up question was asked, i.e., whether or not they had a positive WTP. A considerable number of respondents refused to pay anything for the VCO offered. Therefore, in order to allow for zero-WTP responses, the spike model suggested by Kriström [29] was applied. As the spike model suggested by Kriström [29] is based on the SB DC model, this study tries to modify the spike model for the OOHB DC model following the procedures proposed by Yoo and Kwak [30] to adjust it for the DB DC model.

For the people who were asked the additional follow-up question, the two binary-valued indicator variables can be defined as follows:

$$\begin{aligned}
I_i^{AY} &= \mathbf{1}(i\text{th respondent's response to the additional question is 'yes'})\\
I_i^{AN} &= \mathbf{1}(i\text{th respondent's response to the additional question is 'no'})
\end{aligned} \tag{3}$$

To estimate the distribution of WTP, WTP is assumed to be distributed as a logistic on the positive axis. The log-likelihood function for the OOHB spike model is given by the following:

$$\begin{aligned}
\ln L = \sum_{i=1}^{N} \{ & (I_i^{YY}+I_i^{Y})\ln[1-G_C(A_i^U;\theta)]\\
& +(I_i^{YN}+I_i^{NY})\ln[G_C(A_i^U;\theta)-G_C(A_i^L;\theta)]\\
& +I_i^{AY}(I_i^{N}+I_i^{NN})\ln[G_C(A_i^L;\theta)-G_C(0;\theta)]\\
& +I_i^{AN}(I_i^{N}+I_i^{NN})\ln G_C(0;\theta)\}
\end{aligned} \tag{4}$$

where

$$G_C(A;\theta)=\begin{cases}[1+\exp(a-bA)]^{-1} & \text{if} A>0\\ [1+\exp(a)]^{-1} & \text{if} A=0\,.\\ 0 & \text{if} A<0\end{cases} \tag{5}$$

Thus, the spike is defined by $[1+\exp(a)]^{-1}$. Using Eq. (5), the mean WTP in the spike model can be calculated as $C^+=(1/b)\ln[1+\exp(a)]$. In CV studies, it is common to test for the internal consistency and theoretical validity of the model by estimating the model with covariates. If we want to estimate the model with covariates, in the above equations, a is simply replaced with $a+x_i'\beta$, where x_i is a vector of the explanatory variables, including the bid, and β is a vector of the parameters to be estimated.

5. Results and discussion

5.1. Sample descriptions

Table 1 presents the distribution of responses to the WTP question, showing the total number and percentage of respondents who reported that they would be willing to pay the respective bid level, ranging from KRW 500 to 4,000 for a specific railway travel distance. Note that the percentage of 'yes' responses to the bid amount roughly falls as the bid increases. For example, in the case of 'from lower bid to upper bid,' 21 (70.0%) favored the VCO program at a cost of KRW 500, whereas only 4 (14.8%) approved of it at the level of KRW 4,000.

In addition, Table 2 shows the definitions and sample statistics of respondents' purchasing habits and socioeconomic variables. Among the respondents, 53% knew what renewable energy was and 56% had heard of green electricity. Moreover, 88% of the respondents regarded environmental preservation as important. These points highlight respondents' high level of concern about climate change.

The average monthly income of the respondents in this study was not less than KRW 1.30 million (USD 1,203). The average age of the respondents in this study was 32.3 years and the average level of education was high-school graduation. The sample was evenly split across males and females.

Table 1
Distribution of responses by the bid amount.

Bid (KRW)	From the lower bid to the upper bid				From the upper bid to the lower bid			
	yes–yes	yes–no	no–yes	no–no	yes	no–yes	no–no–yes	no–no–no
500/1500	9 (30.0%)	12 (40.0%)	0 (0.0%)	9 (30.0%)	8 (33.3%)	3 (12.5%)	3 (12.5%)	10 (41.7%)
1000/2000	11 (29.7%)	10 (27.0%)	3 (8.1%)	13 (35.1%)	7 (22.6%)	5 (16.1%)	5 (16.1%)	14 (45.2%)
1500/2500	4 (11.4%)	6 (17.1%)	4 (11.4%)	21 (60.0%)	9 (26.5%)	1 (2.9%)	6 (17.6%)	18 (52.9%)
2000/3000	6 (17.6%)	5 (14.7%)	8 (23.5%)	15 (44.1%)	6 (18.2%)	5 (15.2%)	2 (6.1%)	20 (60.6%)
2500/3500	2 (6.5%)	4 (12.9%)	9 (29.0%)	16 (51.6%)	8 (14.3%)	3 (7.1%)	8 (25.0%)	9 (53.6%)
3000/4000	2 (5.4%)	3 (8.1%)	6 (16.2%)	26 (70.3%)	4 (12.5%)	4 (12.5%)	6 (18.8%)	18 (56.3%)
3500/4500	2 (7.4%)	4 (14.8%)	6 (22.2%)	15 (55.6%)	3 (9.4%)	3 (9.4%)	8 (25.0%)	18 (56.3%)
4000/5000	2 (7.4%)	2 (7.4%)	6 (22.2%)	17 (63.0%)	3 (10.7%)	1 (3.6%)	7 (25.0%)	17 (60.7%)

Table 2
Definitions and sample statistics of the variables.

Variables	Definition	Mean	Standard deviation
Renewable	Dummy for the reception of renewable energy (0=don′t know; 1=know well)	0.53	0.49
Green	Dummy for the reception of green electricity (0=don′t know; 1=know well)	0.56	0.49
Environment	Dummy for regarding environmental preservation as important (0=no; 1=yes)	0.88	0.31
Gender	The respondent' sex (0=female; 1=male)	0.50	0.50
Education	The respondent′s level of education (0=at most that of high-school graduates; 1=college and over)	0.54	0.49
Income	The respondent′s monthly income (0=below KRW 5 million; 1=more than KRW 5 million)	0.26	0.44
Age	The respondent′s age (2=twenties; 4=thirties; 6=forties)	4.33	1.62

Table 3
Estimation results of the model.

Variable	Model without covariates	Model with covariates
Constant	−0.0787 (−0.87)	−1.3815 (−3.21)***
Bid	−0.4866 (13.88)***	−0.5235 (13.98)***
Renewable		0.6209 (3.12)***
Green		0.5542 (2.63)***
Environment		0.5725 (1.65)*
Gender		−0.0511 (−0.28)
Education		−0.0173 (−0.08)
Age		0.0199 (0.34)
Income		0.3362 (1.67)*
Spike	0.5196 (23.57)***	0.5231 (22.69)***
Wald statistic [a] (*p*-value) Log-likelihood	555.70 (0.000) −602.54	514.84 (0.000) −578.54
Number of observations	450	

Notes: the *t*-values, computed from the analytic second derivatives of the log-likelihood function, are reported in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

[a] The null hypothesis is that all the parameters are jointly zero, and the corresponding *p*-value is reported in parentheses after the statistic.

Table 4
WTP estimate (per person per ride) for offsetting greenhouse gas emissions.

Mean WTP (unit: KRW)	95% confidence interval	90% confidence interval	*t*-value
1345	1150–1588	1177–1546	11.98***

Notes: the confidence intervals were computed by the use of the Monte Carlo simulation technique suggested by Krinsky and Robb [31] with 5000 replications.

*** denotes statistical significance at the 1% level.

Table 3 shows the results of the estimation. The model was estimated by the maximum-likelihood estimation method. The second column of Table 3 shows the estimation results of the model without covariates. The coefficient for the bid is negative and statistically significant at the 1% level, as expected. That is, the upper bid makes a 'yes' response less likely. The third column of the table describes the estimation results of the model that includes covariates or variables other than the bid amount that one might expect to affect the likelihood of respondents′ voting 'yes'. It is also common to test for internal consistency (theoretical validity) in CV studies by estimating the model with covariates.

The estimated coefficients of the Renewable, Green, and Environment covariates were found to be statistically significant at the 10% level. Individuals, who are already aware of renewable energy and green electricity, and regard environmental preservation as important, are more likely to accept a given bid than others. This result shows that passenger awareness of climate change and environmental attitudes play an important role in consumers' acceptance of the offer. Except for Income, the estimated coefficients of Gender, Education, and Age were not statistically significant at the 10% level. On the whole, the estimation results indicate that the respondents accepted the contingent market and were willing to contribute a significant amount, on average, per household. This willingness varies more with individuals' concerns about and attitudes towards climate change than with their socioeconomic characteristics.

The estimate of the mean WTP is shown in Table 4. The mean WTP for a VCO is estimated as KRW 1345 (USD 1.24) per person per journey. It can be calculated that train passengers in Korea are willing to pay on average KRW 336 (USD 0.3) for every 100 km they travel.[5] The *t*-value is estimated to be 11.98. Based on this, one can reject the hypothesis that the mean WTP is not different from zero and conclude that the mean WTP is statistically significantly different from zero. Moreover, the study adopted the strategy of constructing 90% and 95% confidence intervals for the point estimate of the mean WTP in order to allow for any uncertainty, rather than only reporting the point estimate. To this end, the Monte Carlo simulation technique of Krinsky and Robb [31] was used.

[5] According to Brower et al. [6], air passengers are willing to pay on average 60 eurocents (USD 0.79) for every 100 km they fly, which is more than twice as much as train passengers, and Europeans are relatively willing to pay significantly more than North-American and Asian air travelers.

6. Concluding remarks

This paper attempted to measure how much Korean consumers are willing to pay for a VCO in the context of railway travel. To this end, the CV method was used. The sequence of steps in the CV design allowed the respondents to reveal their preferences for a VCO program. We have shown how the research builds on the existing literature by eliciting households′ WTP from individuals. The overall results show considerable scope for the use of the CV approach in the valuation of a VCO program for the metropolitan area of Korea. This exercise provides important insights for both research and policy-making.

For research purposes, beyond the intrinsic relevance of our results in relation to the valuation of a VCO program, this study adjusted and applied the spike model suggested by Kriström [29] to model OOHB DC CV data with zero-WTP responses in order to obtain appropriate welfare measures. In the application reported herein, the OOHB spike model fitted the data well. Given a base design of OOHB DC CV surveys, there are two ways of improving the efficiency of estimation: either increasing the sample size or asking only the 'no' and 'no–no' respondents. Due to the usually high cost of increasing the sample size, asking a follow-up question is an inexpensive way of achieving this objective. Moreover, the spike model can be estimated as easily as the conventional model. Therefore, the OOHB spike model presented in this paper can be said to be theoretically promising and practical.

For policy-making purposes, the results provide a preliminary indication of the benefits of carbon offsets for GHG emissions from railways. A CV survey of 500 households was successfully conducted by a professional polling firm with well-trained interviewers. The results indicated that most respondents knew what renewable energy and green electricity were and that they were concerned about environmental preservation. Thus, many respondents had a high level of concern regarding climate change and a perception of their own responsibility for climate change. Regardless of gender, level of education, and age, those respondents who were more knowledgeable about renewable energy and green electricity, and had more environmental attitudes, were more likely to pay for a VCO program. These results concur with those of MacKerron et al. [5] and Brouwer et al. [6] in showing how the 'subjective' or perceived risk of climate change is an important additional motivation for addressing climate change.

The mean WTP for a VCO program for a specific travel distance is estimated to be KRW 1,345 (USD 1.24) per person. The results of this study are useful starting points for understanding the possible implications of the demand and supply of carbon offsets for GHG emissions from railways. The main preliminary results imply that the consumer demand is on the rise for VCOs and that consumers are willing to shoulder the burden for them regardless of their socioeconomic characteristics, including their age and level of education. The results can offer a useful framework for organizing information about the consequences of alternative actions for mitigating climate change. This valuation information should be used by the KORAIL (Korea Railroad) and MLTM (Ministry of Land, Transport, and Maritime Affairs) in their decisions regarding whether to implement various policy instruments for climate change mitigation. In addition, they should consider incorporating such information in their evaluation of alternative actions.

References

[1] Intergovernmental Panel on Climate Change. Climate change 2007: synthesis report. Geneva, Switzerland; 2007.
[2] Gillenwater M, Broekhoff D, Trexler M, Hyman J, Fowler R. Policing the voluntary carbon market. Nat Rep: Clim Change 2007;6:85–7.
[3] Bumpus AG, Liverman DM. Accumulation by decarbonization and the governance of carbon offsets. Econ Geogr 2008;84(2):127–55.
[4] Taiyab N. Exploring the market for voluntary carbon offsets. London: International Institute for Environment and Development; 2006.
[5] MacKerron GJ, Egerton C, Gaskell C, Parpia A, Mourato S. Willingness to pay for carbon offset certification and co-benefits among (high-) flying young adults in the UK. Energy Policy 2009;37:1372–81.
[6] Brouwer R, Brander L, van Beukering P. A convenient truth: air passengers' willingness to pay to offset their CO_2 emissions. ClimChange 2008;90:299–313.
[7] Lee JS, Yoo SH, Kwak SJ. Public′s willingness to pay for preventing climate change. Appl Econ Lett 2010;17:619–22.
[8] Yoo SH, Kwak SJ, Kim TY. Assessing the benefits of the greenhouse gas emissions reduction policy: a pilot study of Korea. Int J Environ Pollut 2001;15:553–67.
[9] Kotchen MJ, Boyle KJ, Leiserowitz AA. Willingness-to-pay and policy-instrument choice for climate-change policy in the United States. Energy Policy 2013;55:617–25.
[10] Adman F, Karah N, Kumbaroğlu G, Or İ, Özkaynak B, Zenginobuz Ü. What determines urban households' willingness to pay for CO_2 emission reductions in Turkey: a contingent valuation survey. Energy Policy 2011;39:689–98.
[11] Botzen WJW. van den Bergh JCJM. Risk attitudes to low-probability climate change risks: WTP for flood insurance. J Econ Behav Organ 2012;82:151–66.
[12] Rode J, Hogarth RM, Menestrel ML. Ethical differentiation and market behavior: an experimental approach. J Econ Behav Organ 2008;66:265–80.
[13] De Pelsmacker P, Driesen L, Rayp G. Do consumers care about ethics? Willingness to pay for fair-trade coffee J Consum Aff 2006;39(2):363–85.
[14] Banerjee A, Solomon BD. Eco-labeling for energy efficiency and sustainability: a meta-evaluation of US programs. Energy Policy 2003;31:109–23.
[15] Mourato S, Foster V, Ozdemiroglu E. Evaluation health and environmental impacts of pesticide use: implications for the design of eco-labels and pesticide taxes. Environ Sci Technol 2000;34(8):1456–61.
[16] Nyborg K, Howarth RB, Brekke KA. Green consumers and public policy: on socially contingent moral motivation. Resour Energy Econ 2006;28:351–66.
[17] Brekke KA, Kvembokk S, Nyborg K. An economics model of moral motivation. J Public Econ 2003;87:1967–83.
[18] Korean Railroad Research Institute. The status of CO_2 emissions and mitigation options in the domestic railways; 2008. Available at: 〈http://www.krri.re.kr〉.
[19] Korean Railroad Research Institute, Ministry of Land, Infrastructure and Transport. The study of mitigation option of greenhouse gas emissions in railways for climate change. Report; 2010.
[20] Korean Railroad Research Institute. The foreign trends of mitigation policy of greenhouse gas emissions; 2008. Available at: 〈http://www.krri.re.kr〉.
[21] HM Government. Securing the future-delivering UK sustainable development strategy. Report; 2005.
[22] HM Government. Climate change: the UK programme. Report; 2006.
[23] Brent RJ. Applied cost-benefit analysis. Cheltenham: Edward Elgar; 1995.
[24] Mitchell RC, Carson RT. Using surveys to value public goods: the contingent valuation method. Washington, DC: Resources for the Future; 1989.
[25] Yoo SH, Chae KS. Measuring the economic benefits of the ozone pollution control policy in Seoul: results of a contingent valuation survey. Urban Stud 2001;38:49–60.
[26] Arrow K, Solow R, Portney PR, Leamer EE, Radner R, Schuman H. Report of the NOAA Panel on contingent valuation. Fed Regist 1993;58:4601–14.
[27] Cooper JC, Hanemann M, Signorello G. One and one-half bound dichotomous choice contingent valuation. Rev Econ Stat 2002;84:742–50.
[28] Hanemann WM. Welfare evaluations in contingent valuation experiments with discrete responses. Am J Agric Econ 1984;66:332–41.
[29] Kriström B. Spike models in contingent valuation. Am J Agric Econ 1997;79:1013–23.
[30] Yoo SH, Kwak SJ. Using a spike model to deal with zero response data from double bounded dichotomous choice contingent valuation surveys. Appl Econ Lett 2002;9:929–32.
[31] Krinsky I, Robb AL. On approximating the statistical properties of elasticities. Rev Econ Stat 1986;68:715–9.